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TEST PLAN
Structural Load Test

TP-D205-564-1

Bearpaw Ski Installation

BELL 205/210/212/214/412 MODELS

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DE # 02

Revision: **A**
Date: 12.05.16

REVISION RECORD

Revision	Date	Description
A	12.05.16	New Issue

1.0 INTRODUCTION

Dart Aerospace Ltd (DART) is amending Canadian STC SH96-42 and FAA STC SR00571NY to add the installation of the Bearpaw Ski kit on the Bell 205/210/212/214/412 model aircraft. The purpose of the Bearpaw Ski kit is to supplement the previously approved DART Bearpaw kit. The Bearpaw Ski kit will provide increased surface area along the length of the skidtubes to reduce aircraft sinking in exceptionally soft terrain and to maintain tail rotor clearance.

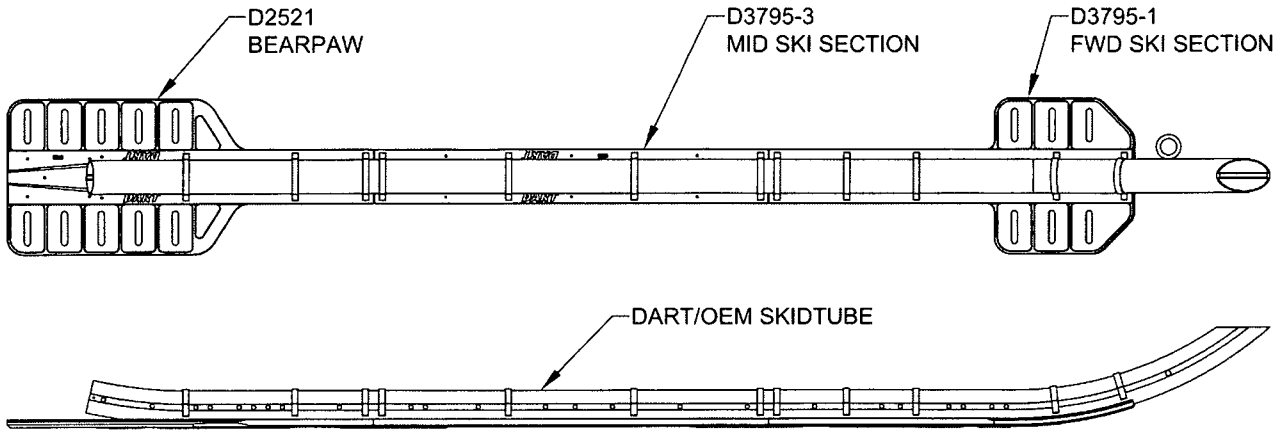


Figure 1 – D205-564-013 Ski Kit

2.0 PURPOSE

The purpose of this test plan, TP-D205-564-1, is to outline the structural testing to be conducted by Dart Aerospace Ltd. on the D205-564-013 Bearpaw Ski kit in order to show compliance to the requirements of FAR 29.301/303/305/307/337 per ACR-D205-564-2. Since the D2521 Bearpaw has been previously approved per SH96-42/SR00571NY it will not be addressed in this report.

3.0 LOADING

In accordance with the requirements of FAR 29.301 and FAR 29.303, a standard factor of safety of 1.5 will be used to design to ultimate loads. Per the memorandum put out by the FAA (see Appendix A of this report), the Skis must meet the following strength requirements:

Note: The coordinate systems referenced in the following document are cartesian coordinates of which the X-direction corresponds with the longitudinal axis of the helicopter, Y-direction corresponds with the lateral axis of the helicopter and the Z-direction represents the vertical axis.

3.1 Ground Loads – A limit load is obtained based on the static weight of the aircraft and is applied as a triangular distribution with the peak load at the skidtube center-line (because the ski is non-metallic and flexible). Since the C.G. and gross weight varies between the applicable aircraft, each applicable combination of C.G. location and gross weight was calculated and summarized in Appendix B. Only the most forward C.G. positions are considered since they will create the most severe loading condition on the D3795-1 FWD Ski Section and D3795-3 MID Ski Section.

3.1.1 Physical Properties

$A_{fwd} = 486in^2$	Ground contact area for the D3795-1 FWD Ski Section (see Figure 2)
$A_{mid} = 318in^2$	Ground contact area for the D3795-3 MID Ski Section (see Figure 2)
$A_{aft} = 618in^2$	Ground contact area for the D2521 Bearpaw (see Figure 2)
$W_{fwd} = 13\ lb$	Weight of D3795-1 FWD Ski Section (Conservative estimate from SolidWorks Model)
$W_{mid} = 8.5\ lb$	Weight of D3795-3 MID Ski Section (Conservative estimate from SolidWorks Model)
$W_{aft} = 14\ lb$	Weight of D2521 Bearpaw (Conservative estimate from SolidWorks Model)

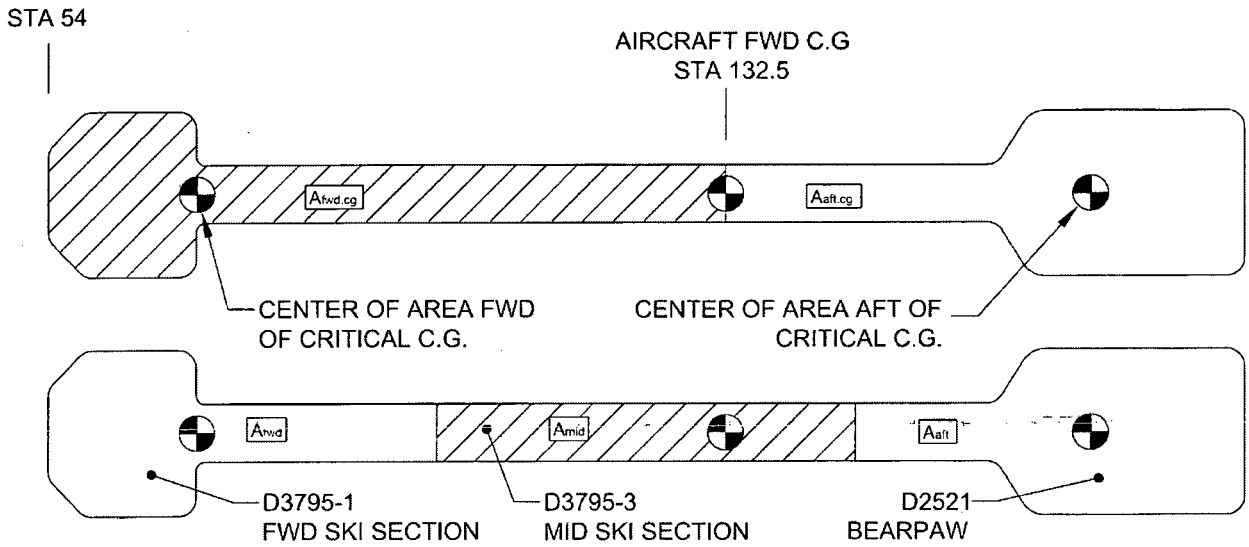


Figure 2 – Contact area constants for calculation of ground loads

3.1.2 Upward Ground Load (Z-Direction) - To calculate the upward ground load on the D3795-1 FWD Ski Section and D3795-3 MID Ski Section, a moment balance about the aircraft C.G. was used. The various forward C.G. and Gross Weight combinations are shown in Table 2 located in Appendix B. The forward most C.G. location is used since it will result in the most severe loading condition on the D3795-1 FWD Ski Section and D3795-3 MID Ski Section. Below is a summary of the most severe loading conditions on the D3795-1/-3 Ski Sections as a result of calculations in Appendix B.

$P_{G.Z.fwd} = 1843\ lbf$	Vertical ground limit load on D3795-1 FWD Ski Section (See Appendix B)
$P_{G.Z.mid} = 1340\ lbf$	Vertical ground limit load on D3795-3 MID Ski Section (See Appendix B)

3.1.3 Longitudinal Ground Load (X-Direction) – The longitudinal ground load is as a result of the Ski assembly sliding on the ground. The following calculations assume a coefficient of friction of 0.50 between the ground and the Ski assembly based on FAR 29.501(c)(1) which specifies that the vertical reactions must be combined with horizontal drag reactions that are 50% of the vertical reactions.

$P_{G.X.fwd} = (P_{G.Z.fwd})(0.50)$
$P_{G.X.fwd} = 922\ lbf$ — Longitudinal ground limit load on D3795-1 FWD Ski Section as a result of dragging

$P_{G.X.mid} = (P_{G.Z.mid})(0.50)$
$P_{G.X.mid} = 670\ lbf$ — Longitudinal ground limit load on D3795-3 MID Ski Section as a result of dragging

3.1.4 Lateral Ground Load (Y-Direction) – The lateral ground load is as a result of the Ski assembly sliding on the ground. The following assumes a coefficient of friction of 0.50 between the ground and the Ski assembly as outlined in Section 3.1.3 above.

$P_{G.Y.fwd} = (P_{G.Z.fwd})(0.50)$
$P_{G.Y.fwd} = 922\ lbf$ — Lateral ground limit load on D3795-1 FWD Ski Section as a result of dragging

$P_{G.Y.mid} = (P_{G.Z.mid})(0.50)$
$P_{G.Y.mid} = 670\ lbf$ — Lateral ground limit load on D3795-3 MID Ski Section as a result of dragging

3.2 Air Loads – The air loads on the Ski assembly are calculated based on the dynamic pressure, q, on each section of the assembly. The calculation uses the most conservative never exceed velocity (Vne) and a force co-efficient of Cn = 0.55. The air loads occur in the vertical (Z-Direction) and longitudinal (X-Direction) directions.

$C_n = 0.55$ — Force co-efficient (per Appendix A)
$\rho = 0.00238\ slug/ft^3$ — Air Density
$V_{ne} = 270\ ft/s$ — Never exceed velocity (See BHT-214ST-FM)
$A_{yz.fwd} = 51in^2$ — Projected area in Y-Z plane of D3795-1 FWD Ski Section

$P_{A.Z.fwd} = (0.5)(A_{fwd})(C_n)(\rho)(V_{ne}{}^2)$
$P_{A.Z.fwd} = 161\ lbf$ — Limit vertical air load on D3795-1 FWD Ski Section

$P_{A.X.fwd} = (0.5)(A_{yz.fwd})(C_n)(\rho)(V_{ne}{}^2)$
$P_{A.X.fwd} = 17\ lbf$ — Limit longitudinal air load on D3795-1 FWD Ski Section

$P_{A.Z.mid} = (0.5)(A_{mid})(C_n)(\rho)(V_{ne}{}^2)$
$P_{A.Z.mid} = 105\ lbf$ — Limit vertical air load on D3795-3 MID Ski Section

Note: *Air loads in the longitudinal direction for the D3795-3 MID Ski Section are negligible and therefore were not calculated above.*

3.3 Maneuvering Loads - Per 29.337(a), limit maneuvering load factors of 3.5 positive and 1.0 negative must be applied to the weight of the Ski assembly when considering loading of the Ski assembly in flight. Considering the worst case of 3.5:

$MF = 3.5$ — Limit maneuvering load factor

$P_{m.z.fwd} = (W_{fwd})(MF)$
$P_{m.z.fwd} = 46\ lbf$ — Limit vertical maneuvering load on D3795-1 FWD Ski Section

$P_{m.z.mid} = (W_{mid})(MF)$
$P_{m.z.mid} = 30\ lbf$ — Limit vertical maneuvering load on D3795-3 MID Ski Section

3.4 Load Summary – The following is a summary of critical loading conditions as a result of ground, air and maneuvering loads calculated above.

Table 1 - Load Summary

Affected Ski Section	Load Type	Limit Load (lbf)	Ultimate Load (lbf)	Load Direction
D3795-1 FWD Ski Section	Ground	1843	2765	Upward
	Ground	922	1383	Aft
	Ground	922	1383	Sideward
	Air	161	242	Downward
	Air	17	26	Aft
	Maneuvering	46	69	Downward
D3795-3 MID Ski Section	Ground	1340	2010	Upward
	Ground	670	1005	Aft
	Ground	670	1005	Sideward
	Air	105	158	Downward
	Air	N/A	N/A	Aft
	Maneuvering	30	45	Downward

Note: *Only highlighted loads in Table 1 require substantiation.*

4.0 TEST CONFIGURATION

Figure 3 shows the upwards load distribution and corresponding bending moment diagram for the D3795-1 FWD Ski Section. The D3795-3 MID Ski Section has a similar bending and shear distributions.

The maximum bending moment can be determined as follows:

$M_{max} = \frac{P}{6W^2} \bullet Y^3$ Maximum bending moment along Y direction

$W_1 = 9.5\ in$ Half width of D3795-1 FWD Ski Section (widest section)

$W_2 = 3.3\ in$ Half width of D3795-3 MID Ski Section

The maximum bending moment on the D3795-1 FWD Ski Section is:

$M_{max.fwd} = \frac{P_{G.Z.fwd} \bullet W_1}{6}$ Maximum bending moment in Y direction on D3795-1 FWD Ski Section along centerline of Ski (at limit load)

$M_{max.fwd} = 2918\ lbf \bullet in$

The maximum bending moment on the D3795-3 MID Ski Section is:

$M_{max.mid} = \frac{P_{G.Z.mid} \bullet W_2}{6}$ Maximum bending moment in Y direction on D3795-3 MID Ski Section along centerline of Ski (at limit load)

$M_{max.mid} = 737\ lbf \bullet in$

Note: *Since the bending moment on the D3795-1 FWD Ski Section is significantly higher than the bending moment on the D3795-3 MID Ski Section, only the FWD Ski Section will be tested under bending loads.*

The triangular upwards load distribution is difficult to apply to the D3795-1 FWD Ski Section. Therefore, to simulate the bending and shear loads into the D3795-1 FWD Ski Section at the same time, the loads will be applied to the D3795-1 FWD Ski Section at w/3 from the centerline as shown in Figure 4a. To simulate the maximum bending moments over the full width, a second test will be conducted with smaller loads applied to the edges of the D3795-1 FWD Ski Section as shown in Figure 4b.

The D3795-1/-3 FWD/MID Ski Sections will be installed on skidtubes/saddles that are representative of the Bell 205/210/212/214/412 model skidtube/saddle configurations. Upward, downward, aftward, and sideward loads will be applied as shown in Figures 4, 5, 6 and 7 respectively. To be conservative, when the loads are applied in the upwards and downwards directions, they will only be applied over the widest and most forward portion of the D3795-1 FWD Ski Section. Limit loads will be applied for a minimum of 15 seconds and the Ski and clamps will be inspected for permanent deformation. Ultimate loads will be applied for 3 seconds and the Ski Sections as well as clamps will be inspected for failure. Loads will be applied with a hydraulic cylinder and measured with a calibrated load cell or applied with calibrated sandbags.

The D205-564-013 Ski kit will include D3796-041 and D3796-043 Wearplates to protect the D3795-1, D3795-3 and D2521 from damage. The ICA will allow the wearplate to be worn through before it is replaced. To qualify this damage, the upwards and downwards test will be conducted with the D3796-041 fwd wearplate installed and the wearplate removed.

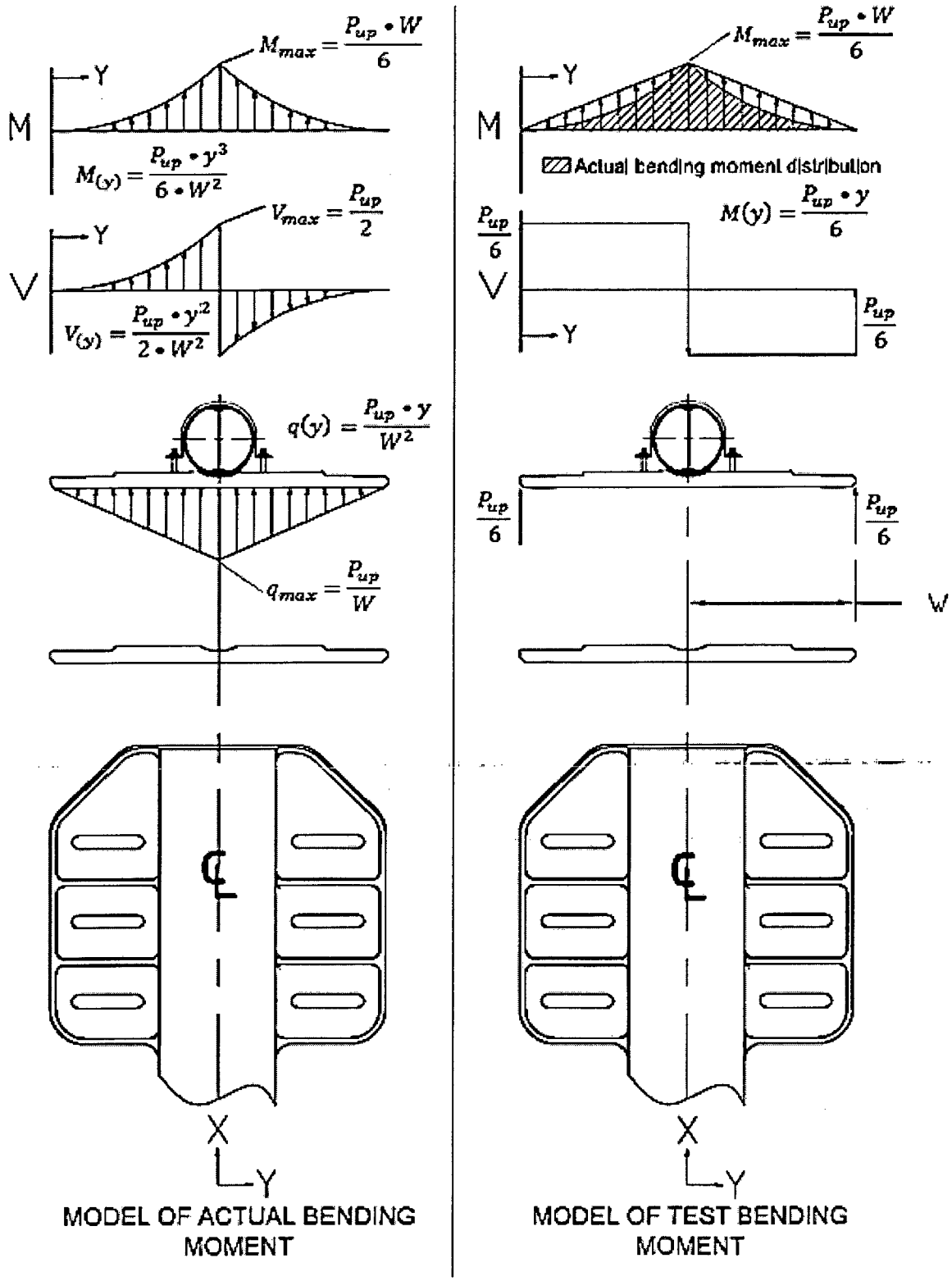


Figure 3 – Upwards Loading Bending and Shear Diagrams

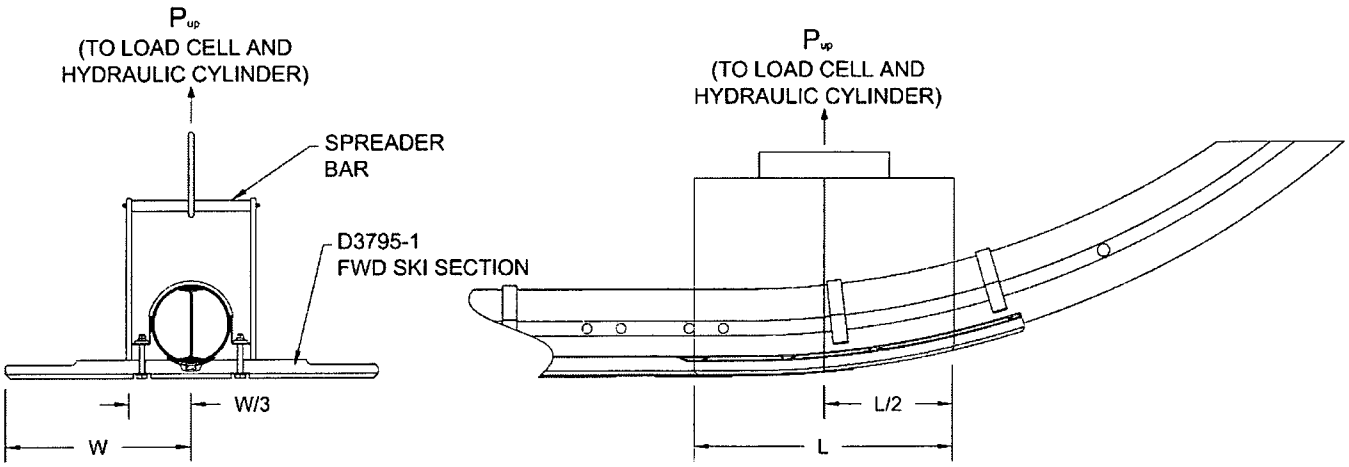


Figure 4a – Test Setup: Upward Loading Condition #1

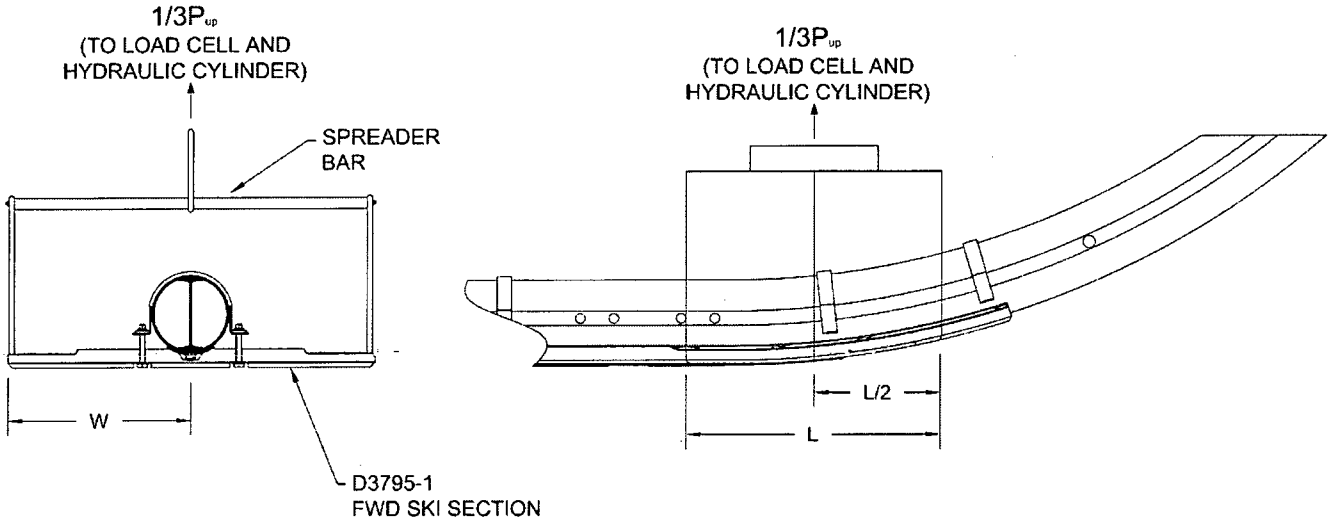


Figure 4b – Test Setup: Upward Loading Condition #2

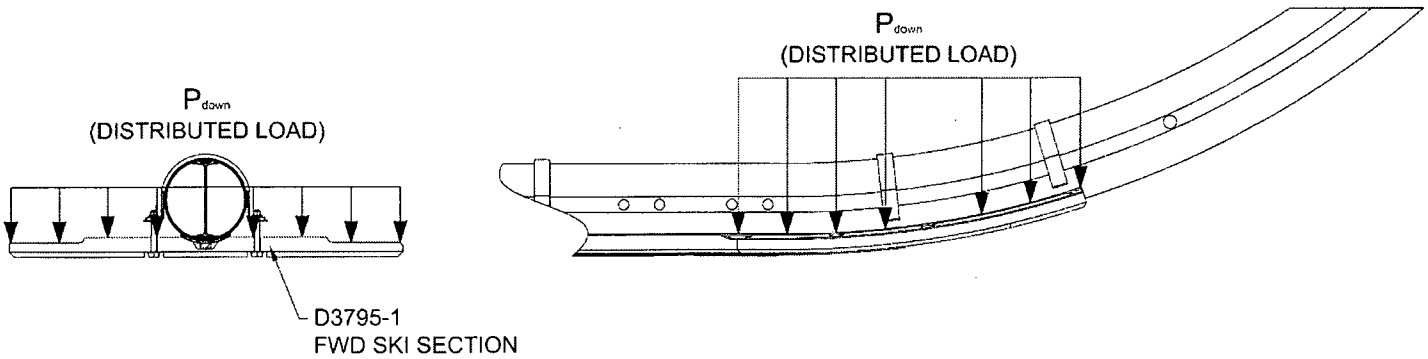
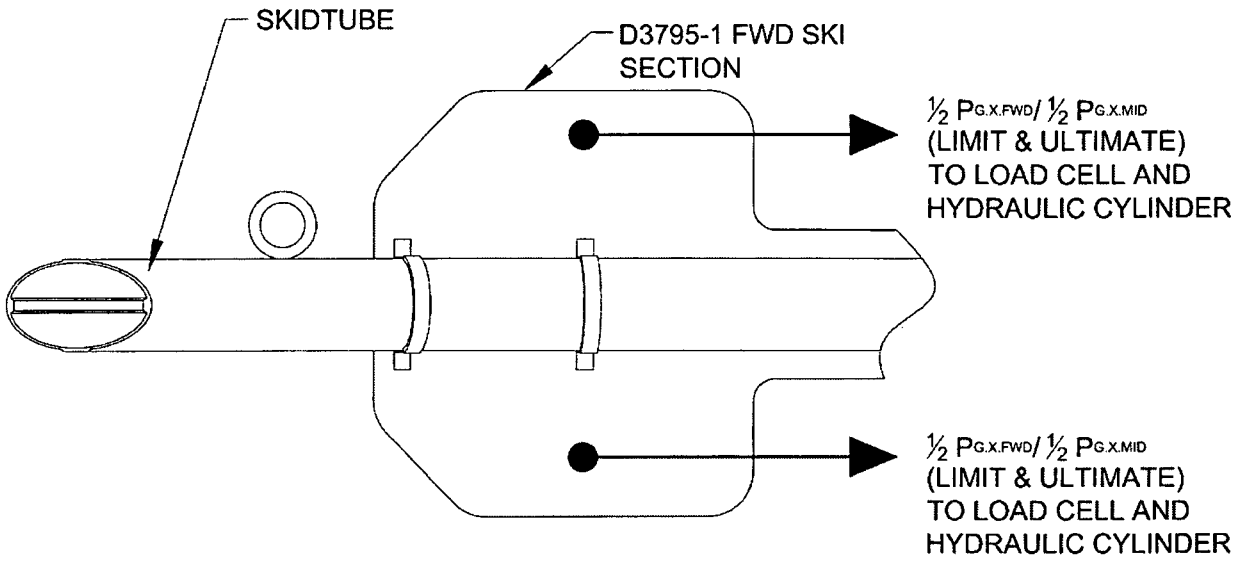


Figure 5 – Test Setup: Downward Loading Condition



NOTE: LOADS TO BE APPLIED TO AFT END OF D3795-1/-3 SKI SECTIONS TO ENSURE THEY ARE LOADED IN TENSION, NOT COMPRESSION.

Figure 6 – Test Setup: Aftward Loading Condition

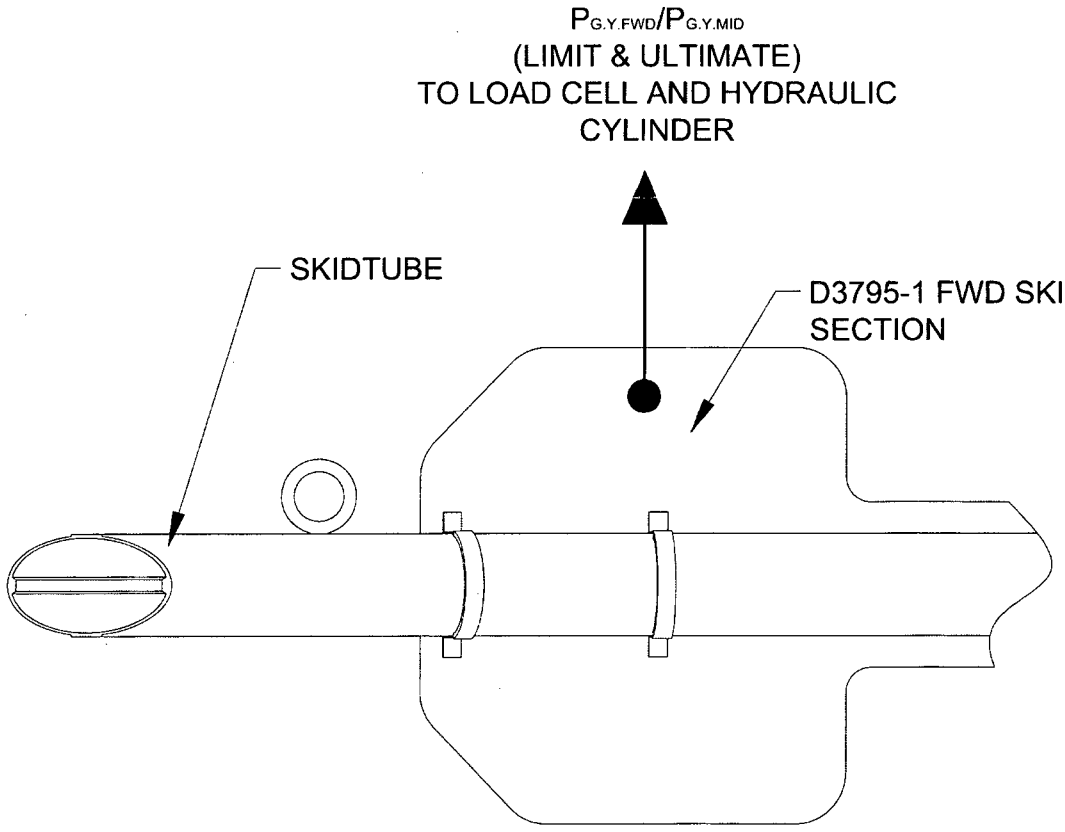


Figure 7 – Test Setup: Sideward Loading Condition

5.0 TEST SPECIMENS

ICA-D205-564 will allow for a maximum 0.125 in (3.18 mm) wear as long as the centerline thickness is not less than 0.25 in (6.35 mm) thick. Therefore to qualify the damage limits in ICA-D205-564, the D3795-1/-3 Ski Sections will be machined to their minimum allowable thickness of 0.25" to simulate maximum allowable wear for testing.

6.0 TEST PROCEDURE

The following procedure will be used in conducting the testing:

1) Assemble the damaged D3795-1/-3 Ski Sections onto skidtube/saddle per D205-564 Rev. H including the D3796-041 FWD Wearplate.
2) Configure the test setup per Section 4 as applicable.
3) Apply the limit loads (See Table 1) to the D3795-1/-3 Ski Sections per Section 4 as applicable. Apply the load for at least 15 seconds.
4) Release limit load. Measure for any permanent deformation of the D3795-1/-3 Ski Sections. Inspect the clamps, hardware and tube area for permanent deformation or failure.
5) Remove wearplate (up/down tests only) and repeat steps 3 and 4 to qualify damage limits.
6) Reinstall wearplate and apply ultimate load (See Table 1) to the D3795-1/-3 Ski Sections per Section 4 as applicable. Apply the load for at least 3 seconds.
7) Release ultimate load. Inspect the ski assembly, clamps, hardware and tube area for failure. Take photos of the condition of the Ski kit.
8) Remove wearplates (up/down tests only) and repeat steps 6 and 7 to qualify damage limits.

7.0 CONFORMITY INSPECTION

An ANB043 Conformity Inspection Record will be completed by Dart's DQA (Director of Quality Assurance) Pat Smith confirming that:

1) All parts in the D205-564-013 Bearpaw Ski kit that are being tested have been manufactured per MDL-D205-564 Rev. C and damaged per Section 5.0 of this Test Plan.
2) The portions of the D205-564-013 Bearpaw Ski kit that are being tested have been installed in accordance with D205-564 Rev. H.
3) The test setup is per Section 4.0 of this Test Plan.
4) The loads applied during the test are calibrated.

8.0 TEST LOCATION

The test will be conducted at Dart's Test Lab located at 1270 Aberdeen St. in Hawkesbury, Ont.

9.0 TEST REPORT

Test report TR-D205-564-1 will be prepared to summarize the results of this test program. This test report will summarize the results of this test and include all measured data, before and after photographs of the tested Ski Sections, photos of the test setup, and a copy of the aforementioned ANB043 form.

10.0 ACCEPTANCE CRITERIA

The test will be deemed successful if the D205-564-013 Kit components do not permanently deform under any of the limit loads or fail under any of the ultimate loads listed in this test plan. Failure is defined as cracking or buckling of any component of the D205-564-013 Kit.

11.0 CONCLUSION

It must be concluded that if the test is conducted in accordance with this test plan, TP-D205-564-1, and the results of the test meet the acceptance criteria stated in Section 10 of this test plan, the Dart D205-564-013 Bearpaw Ski kit meets the requirements of FAR 29.301/303/305/307/337 per ACR-D205-564-2 and will be structurally acceptable for installation onto Bell 205/210/212/214/412 aircraft.

12.0 WITNESS

This Test will be witnessed by Dart DE #02 David Shepherd on behalf of Transport Canada.

APPENDIX A

FAA Memorandum:
Applicable Requirements for Helicopter Landing Gear "Bear Paw" Installations

Revision: A
Date: 12.05.16

APPENDIX B

Sample Calculation for Critical Combination of C.G. & Gross Weight

The following is a sample calculation used to determine the maximum loads on the D3795-1 FWD Ski Section and D3795-3 MID Ski Section. The sample calculation uses the critical combination of C.G. position and gross weight limitations resulting in the highest load on the D3795-1 FWD Ski Section. The table at the end of this Appendix summarizes the results of all other combinations of C.G. and gross weight combinations.

Constants

$C.G. = 132.5\ in$	(Critical forward C.G. ref TC H6SW)
$GW = 12250\ lb$	(Critical gross weight ref TC H6SW)
$A_{fwd.cg} = 711\ in^2$	(Contact area forward of C.G. position)
$A_{aft.cg} = 711\ in^2$	(Contact area aft of C.G. position)
$d1 = 47\ in$	(Length constant ref Figure 8)
$d2 = 84\ in$	(Length constant, ref Figure 8)
$A_{fwd} = 486\ in^2$	(Area of D3795-1 FWD Ski Section)
$A_{mid} = 318\ in^2$	(Area of D3795-3 MID Ski Section)
$A_{aft} = 618\ in^2$	(Area of D2521 Bearpaw)

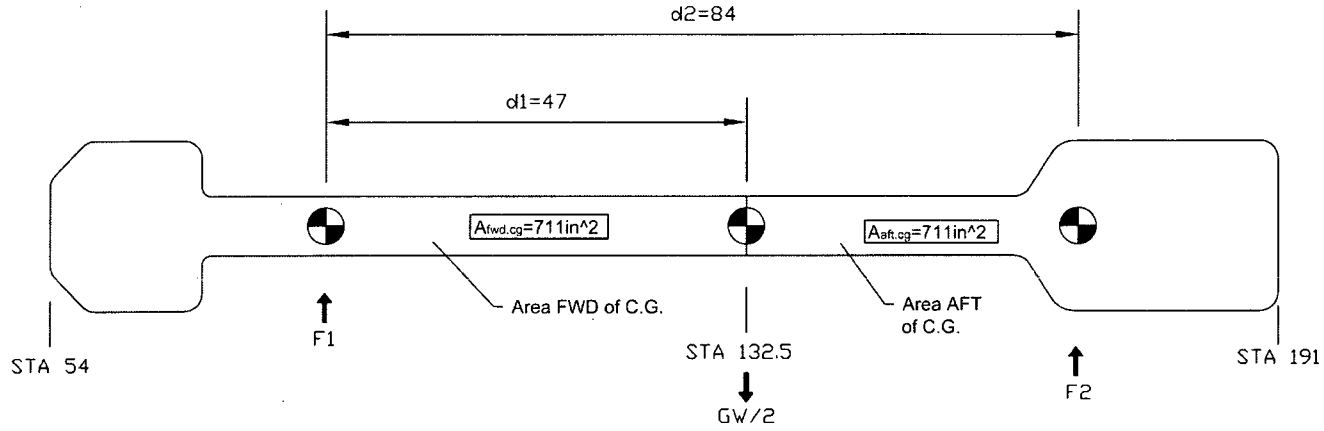


Figure 8 – Calculation constants for C.G. of 132.5 in and gross weight of 12,250 lb

Taking a sum of moments about the forward center of area and solving for F2,

$\Sigma M_{F1} = 0$

$F_2 = \dfrac{GW \bullet d1}{2 \bullet d2}$ — Force exerted at aft center of area portion of the ski assembly (ref Figure 8)

$F_2 = 3427\ lbf$

$F_1 = \dfrac{GW}{2} - F_2$ — Force exerted at fwd center of area portion of ski assembly (ref Figure 8)

$F_1 = 2698\ lbf$

Since the ski assembly is made of three load distributing components, the load on each section can be determined by distributing the load based on fractional area.

$$P_{fwd} = F_1 \bullet \frac{A_{fwd}}{A_{fwd.cg}}$$

P_{fwd} =1844 lbf — Upward load carried by the D3795-1 FWD Ski Section

$$P_{aft} = F_2 \bullet \frac{A_{aft}}{A_{aft.cg}}$$

P_{aft} =2979 lbf — Upward load carried by the D2521 Bearpaw

$$P_{mid} = \frac{GW}{2} - P_{fwd} - P_{aft}$$

$P_{mid} = 1302\ lbf$ — Upward load carried by the D3795-3 MID Ski Section

Refer to Table 2 for a summary of the various C.G. and gross weight combinations and there effect on load distribution through the D3795-1, D3795-3 and D2521 Sections. The worst case is used for the analysis in Section 3.0 of this report.

Table 2 – Summary of various combinations of C.G. and Gross Weight

Type Cert.	Affected Aircraft	C.G. location (inches)	Gross Weight (lb)	Upward Force (lbf)		
				D3795-1 (P_{fwd})	D3795-3 (P_{mid})	D2521 (P_{aft})
H1SW	Bell 205	127	8500	1457	733	2060
	Bell 210	126	7500	1298	616	1836
H4SW	Bell 212	134	11200	1617	732	3250
	Bell 412	130	8800	1392	662	2346
H6SW	Bell 214	137	13800	1829	1340	3731
		132.5	12250	1843	1302	2980